

Connect time - The period your cellular phone is in radio contact with a cell site, not to be confused with the length of time your conversation lasts. Connect time is measured from the time it goes off when you press the END key. See also END key, IN USE indicator, SEND key.

Consolidated Carrier - A carrier authorized to provide telecommunications services both within and outside World Zone 1 using the North American Numbering Plan and the international dialing plan, respectively.

Control head - The part of a cellular phone installation, generally located near the handset, that acts as the "go-between" between the phone user and the transceiver/logic unit. In some phones, the control head is the handset.

Control signal - A signal sent by a cell site to a cellular phone, or vice versa, carrying information necessary to the operation (and cooperation) of the two but not including the audio portion of a conversation. The channels used for control signals are separate from those used for voice. Control signals also flow between a cellular phone's handset and its transmitter/logic unit.

Country Code - A unique 1-, 2- or 3-digit code assigned to countries in the World Numbering Plan. For international dialing purposes, the world is divided into nine zones. The first digit of a country code is the world zone number.

CPU - Central Processing Unit. See also Microprocessor

Dead spot - A location in a cellular system where, for one reason or another, signals do not penetrate. See also Multipath.

Decibel - A unit for expressing the ratio of two amounts of electric or acoustic signal power equal to 10 times the logarithm of this ratio.

Dial Pulse (DP) - Changes in current flow, such as a rotary dial telephone, that provide address (or dialed digits) information.

Dial Tone - An audible signal from a switching system that indicates to a customer that the equipment is ready to receive dial signals.

Digital Rate - The number of bits transmitted per unit of time.

Digital Reference Signal (DRS) - A sequence of digital bits that represents a 1004 Hz to 1016 Hz signal with a power level equal to one milliwatt.

Digital Signal - A signal that has a limited number of discrete states.

Digital Signal Level - One of several transmission rates in the time-division multiplex hierarchy.

Digital Subscriber Signaling System No. 1 - The signaling protocol standard that is used for layers 1, 2 and 3 for the ISDN basic rate and primary rate interfaces.

Digital Transmission - A mode of transmission in which all information to be transmitted is a stream of pulses.

Directional antenna - An antenna or array of antennas designed to concentrate a radio signal in a particular area. It also provides better reception of signals coming from the direction in which it is aimed than it does of signals coming from other directions. Directional antennas are frequently employed when a cell is split. See also Cell Splitting, Omnidirectional antenna.

Disconnect Signal - An on-hook signal indicating the connection is being cleared. The signal responding to a disconnect signal, but applied in the direction opposite to the direction of propagation of the disconnect signal, may also be considered a disconnect signal.

Dropout - A momentary loss of signal. Brief dropouts during a cellular phone conversation can be annoying; longer ones can result in your being disconnected by the system.

DS1 - A digital signal at the rate of 1.544 Mbps that is the equivalent of 24 analog voice channels.

DS3 - A digital signal at 45 Mbps that is the equivalent of 28 DS1 signals, or 672 analog voice channels.

Dual-Tone Multifrequency (DTMF) signaling - A method for transmitting address pulses, and other signaling information, using a set of dual-tones to represent individual characters or numbers. It is primarily used for signaling by station equipment, like telephone sets. The official name for Touch Tone.

Dual NAM - A cellular phone feature that allows it to be registered on more than one cellular system. Multi-NAM phones are also available.

Duplex - Two way. Cellular phones, using separate frequencies for transmission and reception, allow for duplex communications by allowing both parties to talk and listen at once. Push-to-talk systems are not duplex. See also Push-to-talk.

Effective Radiated Power (ERP) - An expression of the signal power which is actually radiated. It is the power of the transmitter, minus any transmitter cabling loss, plus any antenna gain.

Emergency Services Access Point - An emergency services network element that is responsible for answering emergency calls.

END key - The key you press to terminate a call and disconnect you from a cell site's equipment.

End Office (EO) - An EC switching system that terminates station loops and connects the loops to each other and to trunks.

Equal Access - A feature of some switching systems that provides the subscriber the ability to automatically select which Interexchange Carrier (IC) will carry their interLATA traffic without dialing any additional codes.

Error checking - A procedure performed by modems or by computer communications programs to make sure that information sent by modem gets from one computer to the other in good shape. If an error is detected, a request is usually made for the information in question to be retransmitted.

ESN - Electronic Service Number. The serial number of a cellular phone. This information must be contained in the phone's NAM. See also NAM.

Exchange Carrier (EC) - a carrier authorized to provide telecommunications services within one or more access service areas.

FCC - Federal Communications Commission. The government agency responsible for regulating, among other things, cellular telephony.

Feedline - The cable between a radio and antenna that carries radio signals between them. Also called a "transmission line." See also Coax, Hardline.

Fiber optics - The technology that allows electronic signals to be sent in the form of light through hairlike glass "pipes." This technology is being used increasingly in telephone and other communications systems.

Flex antenna - An antenna used with portable phones. It consists of a length of stiff wire, usually with a fiberglass core, covered with an insulating material. Sometimes called a "rubber duckie."

FM - Frequency Modulation. A mode of radio transmission particularly immune to interference. Cellular telephones use FM.

Full-duplex transmission - A communication circuit that can simultaneously transmit and receive information.

Full spectrum - These phones allow the user to access all 832 channels. Previously, phones could only access 666 channels.

Frequency Pair - A set of two frequencies, referred to together as a "channel," used in cellular communications. One frequency is used for transmission, the other for reception. Used together they provide duplex communications. See also Channel, Duplex.

Gelled-electrolyte battery - A type of battery made up of lead-acid cells whose acid electrolyte has been "jellied" to prevent spilling.

Global Title - In SS7, an address such as dialed digits, that does not explicitly contain information that allows message routing in the signaling network.

Global Title Translation (GTT) - In SS7, a procedure that translates a Global Title into a known address that allows message routing in the signaling network.

Ground plane - The surface of land or metal directly beneath an antenna that causes it to radiate and receive radio signals more effectively. A ground plane should be at least a quarter-wavelength in radius of the frequency for which it is intended. See also Wavelength.

Half-duplex transmission - A communication circuit that can transmit or receive information, but not simultaneously.

Handheld phone - A portable phone small enough to be carried and used in the hand. See also Portable.

Handie-Talkie radio - A self-contained transceiver small enough to be carried and used in the hand. The radios police carry in holsters or in their hip pockets are Handie-Talkies, as are handheld cellular phones.

Handoff - The transfer of responsibility for a call from one cell site to the next. See also Cell site.

Handset - The part of a phone you pick up and put to your ear. It contains a miniature speaker to reproduce sound and a microphone to pick it up. The handsets of cellular phones also usually contain a keypad for entering phone numbers and commands and a means of displaying those numbers and responses from the phone. See also Keypad, LCD.

Hands-free phone - A phone that allows you to talk and listen via a microphone and speaker rather than through a handset you have to hold to your ear. Some hands-free phones can even recognize spoken words, allowing you to dial numbers while keeping your hands on the wheel, or wherever.

Hard line - A special type of coaxial cable that uses a solid, rather than braided, outer shield. Hard line is frequently used in fixed cellular installations (cell sites) because of its high efficiency as UHF frequencies. See also Coaxial cable.

High-usage trunk group - A trunk group that is designed to carry the majority of traffic between two switching systems, but has the capability to overflow excess traffic to a tandem route.

HORN Key - The key you press to turn on the "horn alert" circuit that beeps your car's horn when a call is received.

IC - Integrated Circuit. A quarter-inch "chip" of silicon on which can be contained the equivalent of thousands of transistors and other electronic components. The silicon chip is usually empackaged in plastic, with wire leads to be connected to other parts of an electronic circuit.

I Digit - A one-digit information code preceding the billing number in the identification field that either provides information about the type of line originating the call or indicates special characteristics of the billing number.

II Digits - A two-digit information code preceding the billing number in the identification field that either provides information about the type of line originating the call or indicates special characteristics of the billing number.

Immobilized-electrolyte battery - A type of battery made up of lead-acid cells whose acid electrolyte is contained by a spongelike material to prevent spilling.

IMTS - Improved Mobile Telephone Service. Cellular telephony's predecessor, which used a single central transmitter and receiver to service a region. See also Cell, Cellular.

IN USE indicator - The indicator that tells you when your phone is in contact with a cell site. As long as it is lit, you are paying for the connect time on a per minute basis.

Inband Signaling - A type of signaling in which the frequencies or time slots used to carry the signals are within the bandwidth of the information channel.

Inductor - An electrical device that can effectively shorten the required length of an antenna.

Integrated Services Digital network (ISDN) - An integrated digital network in which the same time-division multiplexing switches and transmission routes are used to establish connections for different types of services, such as telephone, data, electronic mail, or facsimile services.

Interexchange Carrier (IC) - A telecommunications common carrier authorized by appropriate regulatory agencies to provide interexchange telecommunications services on an interLATA or interLATA basis within World Zone 1 using the North American Numbering Plan.

Interface - The point of interconnection between a wireless carrier's and a local exchange carrier's communication facilities.

InterLATA - Telecommunication services or functions that originate in one LATA and terminate in another LATA.

IntraLATA - Telecommunication services or functions that originate in one LATA and terminate within the same LATA.

International Carrier (INC) - A carrier authorized to provide interexchange telecommunications services outside World Zone 1 using the international dialing plan; however, the carrier has the option of providing service to World Zone 1 points outside the 48 contiguous states of the United States.

International Routing Code - A 3-digit code within the North American Numbering Plan, beginning with 1, that classifies international calls as requiring either regular or special handling.

ISDN User Part (ISUP) - The functional part of the SS7 protocol which is responsible for providing call control signaling functions required to support basic bearer services and supplemental services for voice and nonvoice applications in an Integrated Services Digital Network.

Keypad - a set of pushbutton electronic switches. The keys on a calculator make up a keypad, as do the buttons on a cellular phone.

kHz - Kilohertz. A measure of audio and radio frequency (a thousand cycles per second). The human ear can hear frequencies up to about 20 kHz. There are 1000 kHz in 1 MHz.

Landline - Traditional, wire-based telephone service, to distinguish it from cellular.

LCD - Liquid Crystal Display. The type of "readout" used by most cellular phones to display the digits of phone numbers as they are dialed or recalled, and other information.

Lead-acid cell - A type of rechargeable power cell using an acid electrolyte. Your car battery is made up of lead-acid cells. See also Gelled-electrolyte cell, Immobilized-electrolyte cell.

Line - A central office connection that usually connects the switching system to customer equipment.

Local Access Transport Area (LATA) - A geographical area adopted at the Bell System divestiture to identify "exchange areas" to be served by the local exchange companies.

Local Exchange Carrier (LEC) - A company which provides intraLATA telecommunications within a franchised territory.

LOCK key - The key you press to "lock" your phone against unauthorized use. The phone is unlocked by entering a personalized four- or five-digit code.

Logic unit - The computer section of a cellular phone, usually combined in the same package with the transceiver.

Loop - A channel between a customer terminal and a central office.

Magnetic-mount antenna - A type of antenna for mobile use. It has a magnetic base that sticks the antenna to a vehicle's roof or trunk lid and allows it to be removed quickly. A magnetic-mount antenna is a worthwhile investment if you use or store your car in a high-risk area, or if you use your phone in a number of different vehicles.

Memory - The ICs in a cellular phone that store phone numbers for instant recall. See also IC.

Message Transfer Part (MTP) - The portion of the SS7 protocol which is responsible for the transfer of signaling messages throughout the SS7 network as required by the application user parts. The MTP comprises Levels 1, 2 and 3 of the SS7 protocol.

Metropolitan Statistical Area (MSA) - Sometimes known as Standard Metropolitan Statistical Areas (SMSAs), MSAs are areas based on counties as defined by the U.S. Census Bureau that are cities of 50,000 or more population and the surrounding counties.

MHz - Megahertz. A measure of radio frequency. One MHz is one million cycles per second. Cellular signals fall in the 800- to 900-MHz portion of the radio frequency spectrum. See also kHz, RF.

Microprocessor - The IC that is the heart and brains of a small computer or computer-controlled device (such as a cellular phone). Frequently referred to as a CPU. See also IC.

Millisecond - One-thousandth of a second.

Milliwatt - One-thousandth of a watt. Handheld cellular phones usually have a maximum output power of 600 milliwatts.

Mobile - Moving. Mobile phones are usually found in vehicles. Portable phones can be mobile, but mobile phones are not necessarily portable. See also Portable.

Mobile Identification Number (MIN) - The 10-digit number that represents a mobile station identity.

Modem - MOdulator/DEModulator. A device used to send information from one computer to another over a telephone system.

MTSO - Mobile Telephone Switching Office. Located between a cell site and a conventional telephone switching office, an MTSO is the link between a cellular phone and the rest of the phone system. An MTSO also handles the routing of traffic within a system.

Multifrequency (MF) pulsing - A method for transmitting address pulses, and other signaling information, using a set of dual-tones to represent individual characters or number. A type of inband address signaling method in which decimal digits and auxiliary signals are each represented by selecting a pair of frequencies from the following group: 700, 900, 1100, 1300, 1500 and 1700 Hz. These audio frequencies are used to indicate telephone address digits, precedence, control signals, such as line-busy or trunk-busy signals, and other required signals. It differs from DTMF in that it uses different frequencies and is used for signaling between switching systems.

Multipath - A condition where a signal from one source is received by several (a direct and any number of reflected) paths. This can frequently cause distortion or loss of signal in cellular communications.

Multiplexing - The processing or equipment for combining a number of individual channels into a common spectrum or into a common bit stream for transmission.

NAM - Numeric Assignment Module. A type of integrated circuit called a PROM that is programmed to contain information specific to your cellular phone such as its ESN and the phone number assigned to it. The information contained in its NAM is what identifies your phone to a cell site and MTSO. See also ESN, IC, PROM.

National Number - The number identifying a calling subscriber station within an area designated by a country code.

Nickel-cadmium cell - A type of "dry" rechargeable power cell. Sometimes called by its trade name, "Nicad."

Nonwireline - Refers to a cellular carrier that has no involvement in providing conventional telephone services. Nonwireline carriers are also known as A carriers. See also A-B switch, Carrier.

North American Numbering Plan (NANP) - A plan for the allocation of unique 10-digit address numbers. The numbers consist of a 3-digit area (Numbering Plan Area) code, a 3-digit office code, and a 4-digit line number. The plan also extends to format variations (e.g., 3-digit and 7-digit address), prefixes (e.g., 1,0,01 and 011) and special code applications (e.g., Service Access Codes like 911).

NO SERVICE indicator - The indicator that tells you when you are in an area where no cellular service is available, or temporarily impossible.

Numbering Plan Area (NPA) - A geographic subdivision of the territory covered by a national or integrated numbering plan. An NPA is identified by a unique 3-digit area code. Another name for your local cellular calling and billing area. This may include neighboring area codes in addition to the one assigned to your phone.

Obsolete, obsolescent - Replaced by something newer. An obsolete or obsolescent cellular phone works just as well as the one that replaces it - it just lacks one or two of the latest convenience features.

Off-hook - The state of a switching system in which the switch-hook contacts are closed, resulting in line current or whatever supervision condition indicates the in-use or request-for-service state.

Off-peak time - The house during which a system is least used. In cellular systems, off-peak time is usually defined as being between 7:00 p.m. and 7:00 a.m., as well as weekends and holidays. Rates are usually lowest during this period. See also Peak time.

Omnidirectional antenna - An antenna that is equally effective in all directions. See also Directional antenna.

On-hook - The state of a switching system in which the switch-hook contacts are open, resulting in a supervision condition that indicates the equipment-idle state.

Operating life - The length of time that a set of batteries will power a handheld or portable phone, usually four to eight hours. This period, as specified, is the maximum possible with the phone in "standby" mode -- off the air waiting for a call. Actually, using the phone decreases the operating life by a factor of about six (one hour of use equals about six hours of standby).

Out-of-band Signaling - A type of signaling in which the frequencies or timeslots used to carry the signals are outside the bandwidth of the information channel.

PCS - Personal Communications Services. A new family of wireless services yet to be fully defined, which may include new radio frequencies, cellular-like services that locate users anywhere at one telephone number, and new data and messaging services.

Peak time - The hours of heaviest usage of a system. In cellular systems, peak time is usually defined as being between 7:00 a.m. and 7:00 p.m., Monday through Friday. Usage rates are higher during peak time than during off-peak time. See also Off-peak time.

Phasing coil - The "pigtail" in a cellular phone antenna and splits a radio signal between them.

Point of Interface (POI) - A reference point of interface between two network elements.

Point of Termination (POT) - the physical location marking the point at which the local exchange carrier's service ends.

Portable - Capable of being carried from place to place. Portable cellular phones contain their own power supplies and can be used anywhere there is service. Portables are further distinguished from transportables by their smaller size and lower power (600 milliwatts instead of 3 watts).

Presubscription - The process used by a customer, where equal access service is available, to select their designated interexchange carrier.

Primary Rate Interface (PRI) - In ISDN; the network interface that provides 1.544 Megabits per second (Mb/s) information transfer as defined in ANSI Standards T1.602 and T1.607.

Program - To store information for carrying out instructions in a computerized system. A NAM is programmed with such information as a phone's ESN and phone number, which allow it to be recognized by a cellular system. See also Burn, ESN, NAM, PROM.

Public Safety Answering Point (PSAP) - The public facility designated to receive and respond to emergency calls.

Public Switched Telephone Network (PSTN) - The telecommunications network commonly accessed by ordinary telephones, key telephone systems, private branch exchange trunks and data transmission equipment that provides service to the general public.

Push to talk - A type of radio communication requiring a speaker to push a button or lever to activate the transmitter. When released, the transmitter turns off, and the receiver comes into action. You can talk or listen with this type of arrangement but not both at the same time. See also Duplex.

Radiotelephone - A mobile or portable telephone that uses radio to link it to the rest of the nation's phone system. Cellular phones are radiotelephones, although they are not usually referred to as such.

RCL (ReCall) key - The key you press, along with a couple of digits, to retrieve a number from your phone's memory. See also Memory.

Read Only memory (ROM) - An electrical circuit that can store encoded information that is not expected to change.

Reuse (of frequencies) - Assigning frequencies to cell sites so that no adjoining cell sites use the same ones. Cell sites out of range of one another can use (or reuse) the same frequencies.

RF - Radio Frequency. Refers to electromagnetic waves having frequencies between about 10 kHz and 300,000 MHz. Sometimes also used to refer to the radio signal itself. See also MHz.

ROAM Indicator - The indicator that tells you when you are out of your local service area and in that of another cellular carrier. If the carrier in the "foreign" area is different from the one the phone is set up for (wireline instead of nonwireline, or vice versa) the ROAM indicator may flash to indicate this. See also A-B switch.

Roaming - Using your cellular phone outside of its "home" service area. Some cellular systems have automatic roaming agreements with others; other systems require you to register with them before you can use their facilities to place or receive calls.

Rubber duckie - See Flex antenna.

Seizure Signal - A signal that is used by the calling end of a trunk or line to indicate a service or access request.

SEND key - The key you press to put your cellular phone "on the air."

Service Access Code (SAC) - The 3-digit codes in the NPA (N 0/1 X) format which are used as the first three digits of a 10-digit address in a North American Numbering Plan dialing sequence. Although NPA codes are normally used for the purpose of identifying specific geographical areas, certain of these NPA codes have been allocated to identifying generic services or to provide access capability, and these are known as SACs. The common trait, which is in contrast to an NPA code, is that SACs are nongeographic.

Service area - The region covered by the cellular service to which you subscribe. Also known as your "number plan area." See also NPA.

Signaling Connection Control Part (SCCP) - The portion of the SS7 protocol which is responsible for connectionless and connection-oriented network services including Global Title Translation.

Signaling Link - In SS7, a bidirectional transmission path for signaling, consisting of two data channels operating together in opposite directions at the same data rate. A signaling link consists of a physical signaling data link together with its transfer control functions used for reliable transfer of a signaling message between nodes in a signaling network.

Signaling Point (SP) - A node in an SS7 signaling network which either originates or receives signaling messages, or transfers signaling messages from one signaling link to another, or both.

Signaling System Number 7 (SS7) An internationally standardized protocol used for out-of-band common-channel signaling that is designed to be used over a variety of digital telecommunication switching networks. It is optimized to provide a reliable means for information transfer for call control, remote network management and maintenance.

Signaling Transfer Point (STP) - A Signaling Point at which a message is received on a signaling link and is transferred to another link. It is neither the source nor the final destination of the message.

Smarts - The "intelligence" imparted to a device by the computer built into it.

Subscriber - One who pays for service from a system.

STO(re) key - The key you press to cause information to be stored in a phone's memory. See also Memory.

TDMA - Time Division Multiple Access. A digital cellular technology that assigns digitized segments of a conversation to one of several time slots on a single channel. See also CDMA.

Toll traffic - Traffic destined for areas beyond the normal local calling area of a local exchange carrier.

Traffic - The communications carried by a system.

Transaction Capability Application Part (TCAP) - The portion of the SS7 protocol which is responsible for information transfer between two or more nodes in the signaling network. The TCAP consists of transaction capabilities that manage remote operations via SCCP message transfer.

Transceiver - A radio transmitter and receiver combined to form a single unit. A cellular phone uses a transceiver to send signals to, and receive them from, the cell site.

Transmission Level Point (TLP) - A point in a transmission system used to determine the power of a test signal, in decibels, with respect to the power of a test signal at a reference point. For example, the power of a test signal at the +7 TLP should be 7dB greater than the power of a test signal at the 0 TLP.

Transportable - See Portable.

Trunk - A transmission channel connected between two network elements in a telecommunications system.

Trunk Group - a group of trunks connected between two elements in a telecommunications system.

UHF - Ultra High Frequency. The UHF band, in which fall the frequencies used by cellular phones, ranges from 300 MHz to 3000 MHz. See also MHz.

Voice messaging - The ability to receive, store, and send voice messages without being on the phone at the same time with another. It allows cellular users to be notified of incoming calls and take messages when their cellular phone is out of the area or turned off, in combination with call forwarding.

Wavelength - The distance from a point on a radio wave to the corresponding point on the next wave. The higher the frequency of a radio signal, the shorter its wavelength. The signals used in cellular telephony have a wavelength of about twelve inches.

Wink - a signal that is a single supervisory pulse usually transmitted as an off-hook signal followed by an on-hook signal where the off-hook signal is of a very short specified duration compared to the on-hook signal.

Wireless - The set of radio-based communications services, including cellular, paging, other mobile radio services, and PCS.

Wireless Carrier (WC) - A generic term used to describe entities providing wireless service. Such entities include, but are not limited to, cellular carriers, radio common carriers, and private carriers.

Wireless phone - A phone, used in conjunction with another phone, that is not directly connected to the phone line. Although cellular phones are wireless, they are not referred to as wireless phones.

Wireline - Refers to a cellular carrier that is also involved in providing conventional telephone service. Wireline carriers are also known as B carriers. See also A-B switch, Carrier.

World Numbering Plan - A plan created by the CCITT that provides each telephone subscriber with a unique number. Each world telephone number consists of a country code followed by the national number as defined in CCITT Recommendations E.163 and E.164.

World Zone 1 (WZ1) - The group of countries in the World Numbering Plan that are identified by the single-digit country code 1. World Zone 1 is defined in CCITT Recommendations E.163 and E.164.

Location Technologies and Field Trial for the Wireless Integration Project (WIP) in Houston

**Prepared for
GTE Telephone Operations**



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1. Introduction

The Wireless technology Integration Project (WIP) has been aggressively pursuing the integration and field demonstration of the various wireline and wireless components that are required to provide the new, Enhanced 9-1-1 (E-911) emergency service. The FCC has developed a set of rules that govern the transition from current, conventional 911 service to E-911 through two implementation phases. Central to the implementation strategy, particularly in its second phase is the use of Location Determination Technologies (LDT)'s that can provide an accurate estimate of the geographic location of the wireless caller. The focus of this segment of the WIP report will be on the analysis and assessment of the location technologies pertaining to E-911, particularly within the context of the late 1996 demonstration in Harris County, Texas.

This report segment will first summarize the critical FCC E-911 requirements (Docket 94-102), which have resulted from extensive efforts within the public safety community and the wireless industry. The key open issues related to the FCC ruling, which are still being debated, will be identified and their possible impacts on the location technologies will be identified. This will set the stage for discussing the state of the 911 practice and the objectives of WIP related to location technologies. A summary review of the various approaches to locating wireless users will then be provided and some top level pros and cons will be presented. The challenges and basic limitations that these technologies have to contend with in the modern cellular environment will be highlighted.

After addressing the general issues on wireless user location determination, focus will shift to discussing the specific example of location technology that was utilized in the WIP demonstration in Harris County, Texas, in December 1996. That system is referred to as "TruePositionTM" and is being developed by the Associated Group Inc. (AGI). Its salient features will be summarized from information that has been made publicly available. The configuration used for the trial in Houston will be described, and the cellular operating environment will be described. The connectivity of the system will be discussed, but briefly since it is addressed elsewhere in the WIP report. The focus of the discussion will be on the connectivities required by the location technology, in particular the technology example at hand in Houston, namely TruePosition, and the E-911 network with which the technology interfaces. Data transfer protocol issues will be discussed at this point.

The tests of the location technology conducted in Houston, in December 1996, will be summarized and their pertinent results provided in a table format to simplify their presentation and comprehension. Focus will be on the E-911 context in the trial and routing of the emergency calls to the proper Public Safety Answering Point (PSAP) identified in that context. Engineering observations on the results and insights into them will be provided.

To conclude, an assessment of the overall performance of the WIP demonstration system and the location technology example utilized will be provided, including issues of technology maturity, risk, deployment feasibility and cost. The next steps envisioned along the path towards a broader scale E-911 implementation with LDT's will be addressed.

2. E-911 Requirements

On October 19, 1994, the FCC issued a notice of proposed rule making (94-102) regarding E-911. Subsequently, on July 26, 1996, the FCC released a report and order (R&O) and a Further Notice of Proposed Rulemaking (FNPRM 96-264) regarding compatibility between wireless systems and E-911 services. In the Report and Order the commission promulgated rules that are largely consistent with a Consensus Agreement arrived at by the Cellular Telecommunications Industry Association (CTIA) and three public safety organizations: APCO, NENA, and NASNA. The CTIA is a trade organization, which includes, among others, many wireless providers and manufacturers as members.

2.1 Requirements per the FCC's Report and Order

The rules adopted call for an E-911 deployment that is over two-phases, spanning five years from the date the rules become effective (October 1, 1996). In Phase I, the wireless carriers (including all cellular and all interactive voice PCS providers) will have, starting 12 months after the date of the rules, and completed no later than 18 months of that date, i.e., April 1, 1998, the capability to provide the PSAP's with wireless 911 caller's Automatic Number Identification (ANI), which is typically a form of the mobile identification number (MIN), and the location of the base station or cell site receiving the 911 call through a "pseudo-ANI". The requirement on the wireless provider applies only if the PSAP has made the investment that is necessary to allow it to receive and utilize that E911 information, and has made a formal request to the carrier to receive that data six months in advance. Also the FCC has made the implementation of the requirement contingent upon the adoption of a cost recovery mechanism, yet to be fully articulated.

The phase I requirement applies to all service activated handsets, including roamers, and apply as well to 911 calls placed directly from a handset without the prior use of a PIN (that may be required of the caller to use to complete a regular cellular call).

The Phase I ANI provision ensures that a PSAP can call back a wireless 911 caller in the event a call is disconnected (assuming the wireless phone has not been turned off or is not directed to voice mail).

The Phase I requirement calls basically for the caller's number and the serving cell/sector. Most wireless carrier switch equipment today contains the capability of making available this ANI and cell identifier available to the interface with the PSAP.

The more challenging requirement set by the FCC is that of Phase II. However, the time frame available for its realization is considerably longer than for Phase I, namely 5 years from the date of the rules, i.e., October 1, 2001. Phase II calls for the wireless carriers to provide to the PSAP's the longitude and latitude of the mobile unit making the 911 call, within a radius of no more than 125 meters (410 feet) in 67% of all cases. The degree of accuracy will use the root mean square (RMS) method to compute the location determination error.

2.2 Further Notice of Proposed Rule Making

The FCC requested comments on a number of controversial issues. It requested comments on whether after the initial five year period, location should be determined within 40 feet in 3 dimensions for 90% of all 911 calls processed. The FCC also solicited comments on cost estimates for provisioning such enhanced location capabilities and on the cost recovery mechanisms to pay for such services.

The FCC also sought comments regarding the development of a minimum latency period to insure that emergency personnel are informed of the 911's caller location in a timely manner. Also comments on the feasibility of continuous tracking during the E-911 call were solicited. The initial numbers of 5 seconds for initial latency and location updating every 10 seconds were provided as examples to spur the debate.

The FCC also requested comments on the handling of multiple air interfaces, in particular, the issue of utilizing a location technology developed for some air interface, e.g., AMPS, when multiple interfaces co-exist that may not all have location technologies available at some point. For example, should a TDMA handset default to analog AMPS when 911 is dialed if no location capability is present for the TDMA interface.

Finally, the FCC solicited comments on how it can monitor the progress of the wireless industry to ensure that the carriers are developing and deploying state-of-the-art technology to meet the E-911 requirements of Phases I and II.

2.3 Open Areas in the Current E-911 Requirements

The FCC's FNPRM touched upon some of the open areas in the E-911 implementation arena, although it opened up more areas of uncertainty. The FCC has refrained from setting or promulgating technical standards for E-911. Instead, it has relied on the parties involved (wireless carriers and manufacturers and public safety organizations) to work in good faith to resolve many of the outstanding implementation issues.

Key among the open implementation issues is how to measure the 125 m accuracy. Is the 67% spatial (over all geographic points in a market), or temporal (over time for a given set of points), or over a sample representative of all calls in a the wireless market area. How would such a sample be composed: proportional to cellular traffic patterns, to 911 call patterns, or simply arbitrary and random. What to use as an accurate location benchmark is still to be specified, although high accuracy Differential GPS (DGPS) may be an obvious candidate in many cases.

Another open area is latency and location tracking during a call. This requirement could rule out or force significant modifications to certain location determining techniques. Additionally, if tracking is required, how would the 67% be measured in this case—would the location error be averaged over time for each call, or will the minimum be taken?

A large open area pertains to interface specifications, or the so-called common channel signaling. Interfaces are to be resolved either through submittal to standards bodies or through mutual agreement on a local or regional level between the PSAP's and the wireless and wireline providers. The FCC will attempt to track the progress of the involved parties in this critical area.

A less immediate open area relates to enhanced accuracy requirements. At this point in time, although more than one location technology vendor could claim to meet the FCC Phase II requirements, none of them really does today, except perhaps under the most controlled of conditions and scenarios. The 125 m accuracy requirement is indeed a challenging requirement for all wireless-network based systems, which are the presumed solution approach based on the Consensus Agreement. An even greater degree of accuracy is likely to require a new family of systems that are heretofore undeveloped and whose cost is certainly unknown. In fact, a 40-foot accuracy requirement may open the door to systems which may use non-traditional approaches to bring down the accuracy well below 125 m. (e.g., handheld or emergency vehicle-mounted homing devices). Such approaches are not really precluded by the FCC docket.

Another open area is how to handle new digital air interfaces that may not yet have location technologies developed to meet the E-911 requirements.

Finally, the issue of cost recovery is still quite open, and is to be worked out somehow between local governmental organizations and the wireless industry.

3. Objectives of the WIP Project Related to Location Determination

As can be seen from the previous section, there are various areas that are open and in need of further specification by the involved parties. The WIP team has taken it upon itself to aggressively attain progress in a number of these critical implementation areas.

The WIP team encompasses major players from the public safety sector, including PSAP's, also wireless carriers, wireless infrastructure manufacturers, location technology developers, and third party E-911 product vendors, e.g., in the database and mapping areas. This broad, multidisciplinary team has the tools and know how to demonstrate the feasibility of the E-911 requirements. Specifically, the objectives of the team have been to demonstrate that ANI and ALI for wireless 911 are feasible and to evaluate the technology to produce both. Location technologies are an essential component to enable an ALI that complies with the Phase II FCC requirement (125m 67% of the time).

The FCC Phase II requirements call for the delivery of call-back ANI and pseudo-ANI, as well as actual caller location in the form of latitude/longitude. The WIP trial had as an objective not only to demonstrate these capabilities, but also to show dynamic routing of the wireless 911 calls to the proper PSAP based on the ANI and the latitude/longitude location. The graphical display of this information on PSAP terminals that have accurate, up to date maps has also been an objective. The WIP also aimed at examining the issues pertinent to the measurement of the location accuracy to determine compliance with FCC Phase II requirement.

These objectives not only address the performance accuracy of the LDT and its deployment and operational challenges, but also the complex issues of interconnecting the LDT processors to the PSAP's, the ALI databases, and the wireless network. This is in terms of physical connectivity as well as in terms of protocols, processing delays, and the proper sequencing of events during wireless 911 calls.

Objective comparative evaluation of multiple location technologies had been an original goal of the WIP team. However, economic and resource limitations of all involved, in particular location vendors, precluded a full realization of this objective. This is discussed in more detail later in Section 5. Consequently, this report will provide a review of the different location determination approaches most pertinent to E-911, and will discuss their potential and

challenges, especially when compared to the traditionally more accurate independent infrastructure location systems (e.g., GPS). This report will also allude to the prominent players and their efforts in each LDT approach and, to the extent possible, their current status.

With the availability of more accurate, latitude/longitude ALI information to the PSAP, the need for graphical display with precise maps is heightened. One of the WIP objectives has therefore been to examine the performance of the LDT vis-à-vis the spatial accuracy of corrected and uncorrected electronic map data bases.

4. Overview of Wireless Network-Based Location Technologies

Location determination systems can be classified as belonging to wireless network-based systems and independent infrastructure systems. All systems of the latter kind, such as GPS and DGPS, and Teletrac which uses terrestrial transmitters, have their own mobile receivers. That receiver would have to be integrated with the wireless (e.g., cellular) handset to provide a location capability to the voice user. Because of the very large embedded base of cellular handsets (about 40 Million, and increasing rapidly), this major drawback for independent infrastructure LDT's makes them unsuitable as a general solution approach for E-911 purposes. However, they do have significant commercial applications such as fleet management.

In the remainder of this section the focus will therefore be on network-based solutions to wireless location. Yet, since the independent infrastructure systems designed and built specifically to provide accurate position determination, they have in general superior positioning performance. A broad comparison of the differences is provided at the end of the section to shed some light on the challenges and inherent limitations of network-based systems. This is important as it may serve to calibrate the public's expectations.

The biggest impediment to a system by system analysis for LDT's is the proprietary nature of these systems. System developers and vendors for LDT's are not willing to share in-depth technical information except under strict non-disclosure rules. This is understandable, since such new system development entails a fairly high degree of investment and risk. Hence what can be done here is a review of the general location determination approaches, and reference some of the key systems that use them based on the limited technical information that is publicly available. The review will encompass more than the present analog cellular system and will include references to the new digital wireless systems currently being rolled out mostly by PCS providers.

Three general approaches exist for network based location determination. These are based on (1) signal power measurement, (2) angle of arrival sensing, and (3) time or time difference of arrival detection. Hybrids that combine more than one of these basic approaches are possible.

4.1 Signal Power Measurement Technology

Systems have been developed that estimate the distance to a base station via measurements of the power received off the base's Forward Control Channel (FCCh). The gradual attenuation of the signal power with distance from the transmitter has been studied extensively. The mobile radio task is to accurately estimate the FCCh power received and to determine the cell site associated with the corresponding control channel. This information is relayed to the LDT's control center (a cellular voice circuit is usually employed to relay this information). The control center determines the distance from the respective cell site by use of the measured power and a propagation law relating power to distance. A minimum of three separate such measurements are needed to determine the mobile's location. The mobile is within the intersection of three "circles".

The main problem with these systems is their inherent unreliable accuracy. Identifying the correct station whose FCCh signal is monitored is sometimes a challenge. More than one cell site that could be received by the mobile may be using the same FCCh and this could introduce ambiguity into the LDT calculations. Also, the station's signal can get attenuated for reasons other than distance, such as passing through walls, foliage, glass or nearby presence of other vehicles. Multipath effects can alter the signal level as well. Furthermore, signal variation associated with the mobile's elevation are difficult to account for.

When the LDT's control center determines that the location accuracy is poor, other means must be employed to enhance accuracy. The additional information can be supplied possibly by direction finding equipment. This approach was utilized in the earliest system by AccuCom Wireless Services (then known as TrackMobile). Accuracies on the order of 500 m were achieved. Since this accuracy was not adequate for, say stolen car recovery, the service concept included a field team that used a handheld direction finder to "zero-in" on the vehicle, assuming the reverse voice channel continued to be transmitted from a hidden transmitter in the vehicle.

4.2 Angle of Arrival (AOA) Measurement Technology

This technique uses the mobile's transmission on the voice channel to determine the Angle of Arrival (AOA) of these transmissions to several cell sites. This technology is also referred to as Direction of Arrival (DOA). AOA has been well developed for military and government applications. Its attraction stems from the fact that no modification is needed to the mobile's equipment. AccuCom, KSI and Engineering Research Associates (E-Systems), are known to have products that make use of this technology.

At the cell sites, the technique normally requires an antenna array — an arrangement of several antennas in a precise fixed spacing. AOA systems typically rely on determining the angle of arrival at several cell sites of the Reverse Voice Channel (RVC). At each cell site, the phases and/or amplitudes (depending on the proprietary algorithm) of the RVC signal received from all antenna elements are compared and the AOA to that cell is determined. The control center uses the data, which is relayed from the cells for the triangulation algorithm, which bases its location estimation on the point of intersection of projected lines drawn out from the cell sites at the angle from which the signal originated.

One of the advantages, and certainly challenges, for AOA systems is their ability to continuously track the voice channel. As the mobile user moves about, cell handoffs take place. These channel handoffs need to be detected by the system and the receivers at the cell sites commanded to retune to the new RVC. This information is sent over the air in AMPS and can be readily extracted also over the air. It could also be obtained from the cellular switch but some delay may be incurred, since such an operation would typically be of low priority at the switch. For new digital wireless systems such as CDMA or GSM, handoff and even initial call and RVC assignment information is only available if the pseudo-noise (PN) code (in case of CDMA) or encryption sequence (in case of GSM) is known. Hence full co-operation of the carrier, and possibly cellular infrastructure equipment vendor, is needed for the system to operate successfully in that environment. This is not an insurmountable problem, only a development complication.

The biggest problem by far that AOA technology developers face is the errors caused by multipath. The classical AOA estimate is based on extracting the phase of a single wave (which propagates along the line of sight) at several points in the antenna array at each site. In a typical metropolitan area, this wave often gets reflected off natural and man-made structures. These reflections can have power stronger than the direct path's (from the mobile to the antenna array), and can introduce significant errors into the AOA estimate. Resolution of such errors can be done if the AOA tracking is based on a continuous transmission such as voice; extracting the AOA from the short pulses used on the Reverse Control Channel is a considerably more difficult task, and is typically not used.